# Quadrature RF Coil & Phased Array Operation at 21.1 T

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## Introduction:

Ultra-high magnetic fields that extend up to 21.1 T (900 MHz for $^1$H) for MRI on vertical widebore systems offer improvements in signal-to-noise ratios (SNR), that can be used to obtain higher spatial resolution and/or lower image acquisition times. The ability to overcome potential $B_1$ inhomogeneities resulting from high frequency effects while maintaining SNR is critical for the successful acquisition of *in vivo* data from pre-clinical animal models.

The MR phased array takes advantage of the increased sensitivity offered by several smaller coils, compared with one large resonator. Most phased array implementations have appeared in the clinical setting where sensitivity enhancements are traded for reduced imaging times via parallel imaging techniques [1]. Variants of phased arrays have also been implemented in high-field pre-clinical systems at 14.1 T and 17.6 T where significant improvements in *SNR* have been shown [2-4].

## Objective:

***In this study, custom RF coil array configurations will be constructed in order to provide improved SNR and parallel imaging functionality at 21.1 T for pre-clinical MR studies.*** Specifically, a transmit-receive quadrature driven saddle pair design for the rodent brain is discussed as well as its extension to multi-channel configurations for improved RF homogeneity and reduced imaging times.

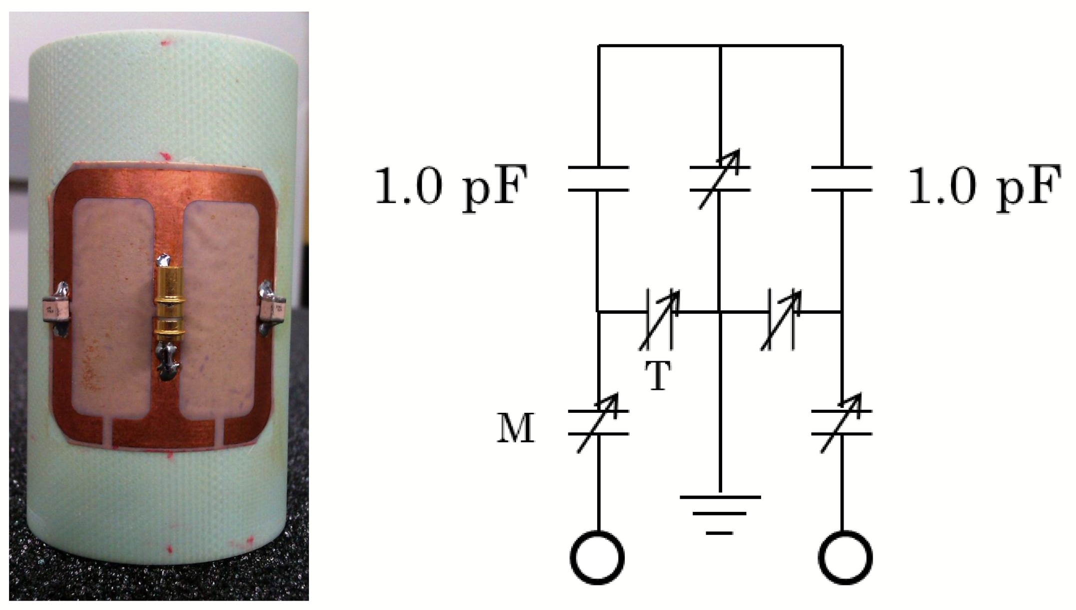



**Fig. 1: Saddle pair quadrature coil with corresponding matching circuit.** Custom ordered copper clad laminates (DuPont Electronic Materials, Research Triangle Park, NC) adhered to a fiberglass epoxy former (G10). Coil dimensions: 32x30 mm on a 3.57 cm O.D. former, resulting in 97.1° of coverage. There is a decoupling capacitor between loops that ranges from 0.5 – 4.5 pF. T & M capacitor range: 0.8 – 8 pF.

## Materials & Methods:

- Quadrature operation: For transmission, a hybrid coupler (R&D Microwaves, East Hanover, NJ) was used to split a single channel into two equal feeds separated by a 90° phase. The same coupler then combines signals from the two coils during reception.

- Quadrature mode performance was assessed using water phantoms and an *ex vivo* C57BL/6 mouse head to measure signal homogeneity and *SNR* in comparison to linear operation using a single coil.

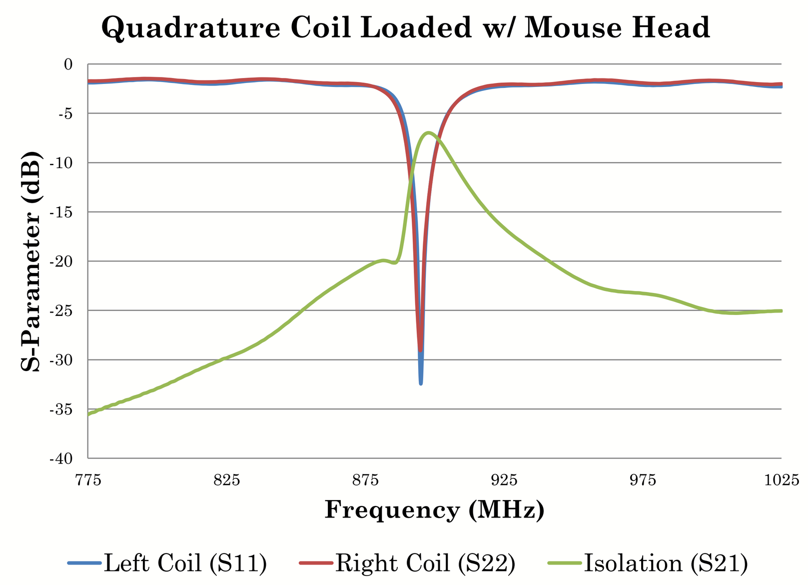



**Fig. 2:** Reflection and isolation plots of the quadrature coil loaded with an *ex vivo* mouse head.

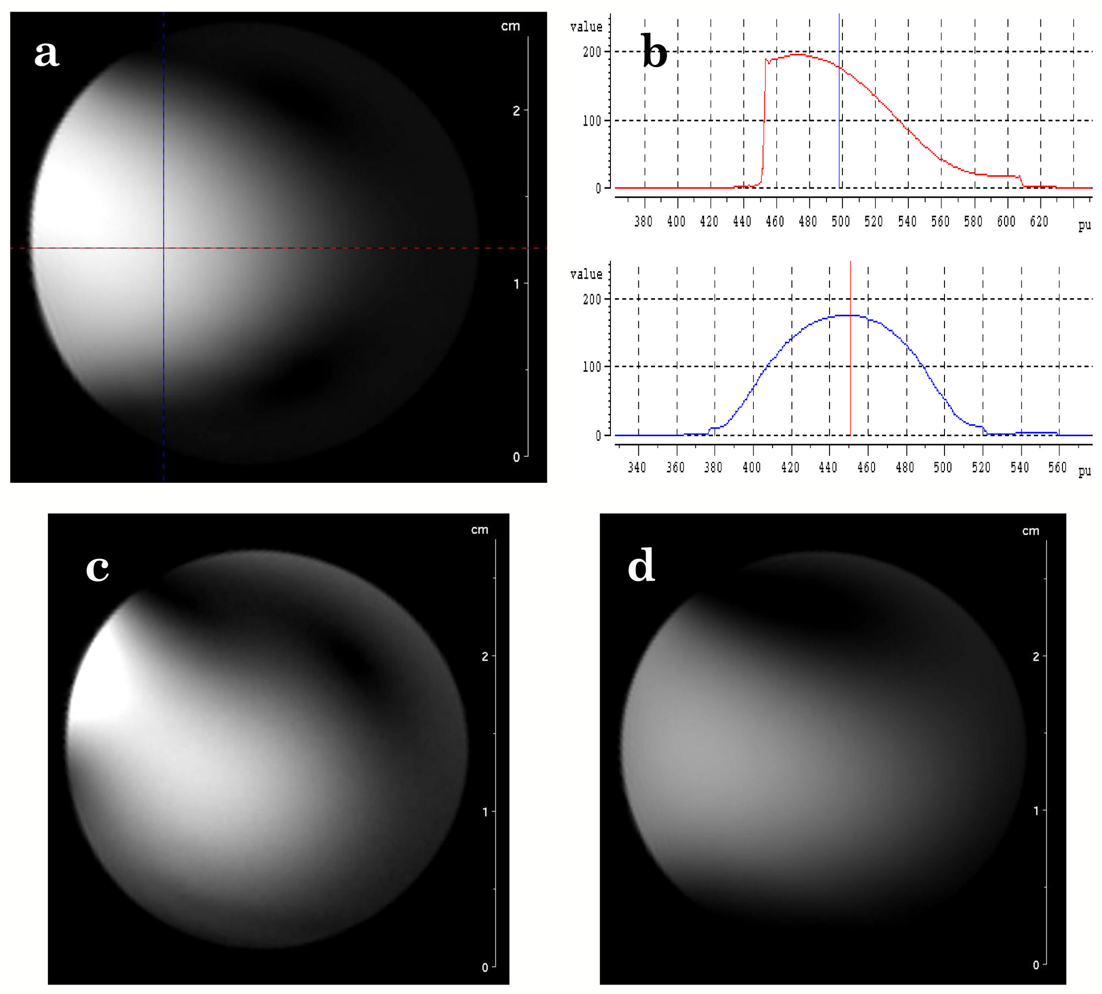
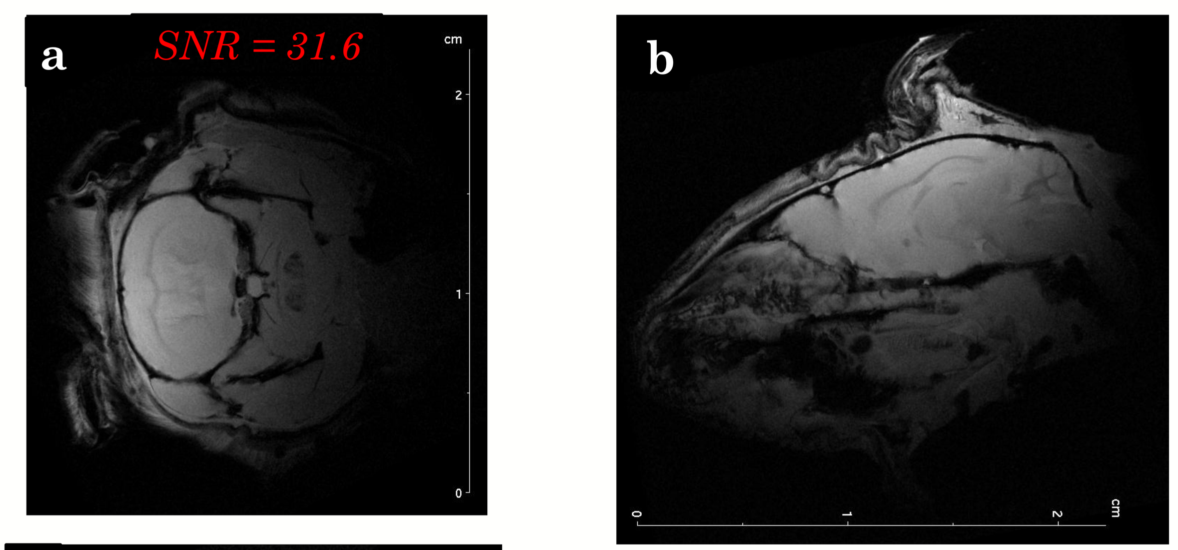



**Fig. 3 DI-Water Phantoms:** (a) Quadrature Mode; (b) signal homogeneity profiles of figure a; (c) excitation with only one loop from quadrature coil; (d) linear coil with dimensions equivalent to entire quad coil.



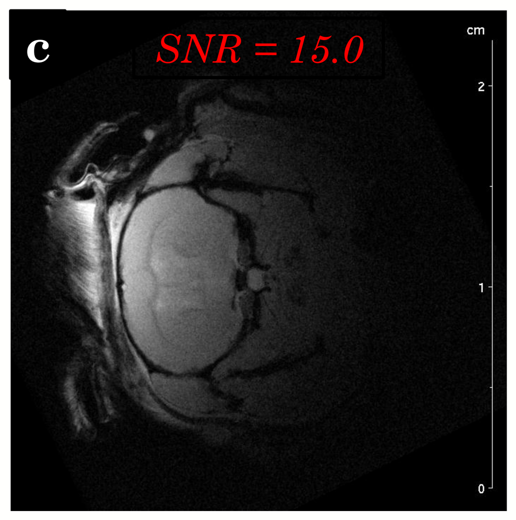




**Fig. 4 C57BL/6 Mouse Head:**
(a) Quadrature Mode – coronal view
(b) Quadrature mode – sagittal view
(c) Exciting only one loop from quadrature coil – coronal view.
SNR calculated from an ROI centered in the entire brain.
Parameters: TE/TR = 4.67/935 ms, FOV = 24x24 mm, Res. = 0.050x0.050 mm, acquisition time = 7.5 mins.

## References & Acknowledgements:

**[1]** Larkman, D. J. and Nunes, R. G., (2007). *Phys. Med. Biol.*, 52: R15-R55; **[2]** Gareis, D. *et al.*, (2006). *Concepts Magn Reson Part B (Magn Reson Engineering)*, 29B: 20-27; **[3]** Zhang, X. and Webb, A., (2004). *Journal of Magnetic Resonance*, 170: 149-155; **[4]** Zhang, X. and Webb, A., (2005). *Concepts Magn Reson Part B (Magn Reson Engineering)*, 24B: 6-14.

MRI data were supported through and acquired at the NHMFL of the Florida State University.

## Results:

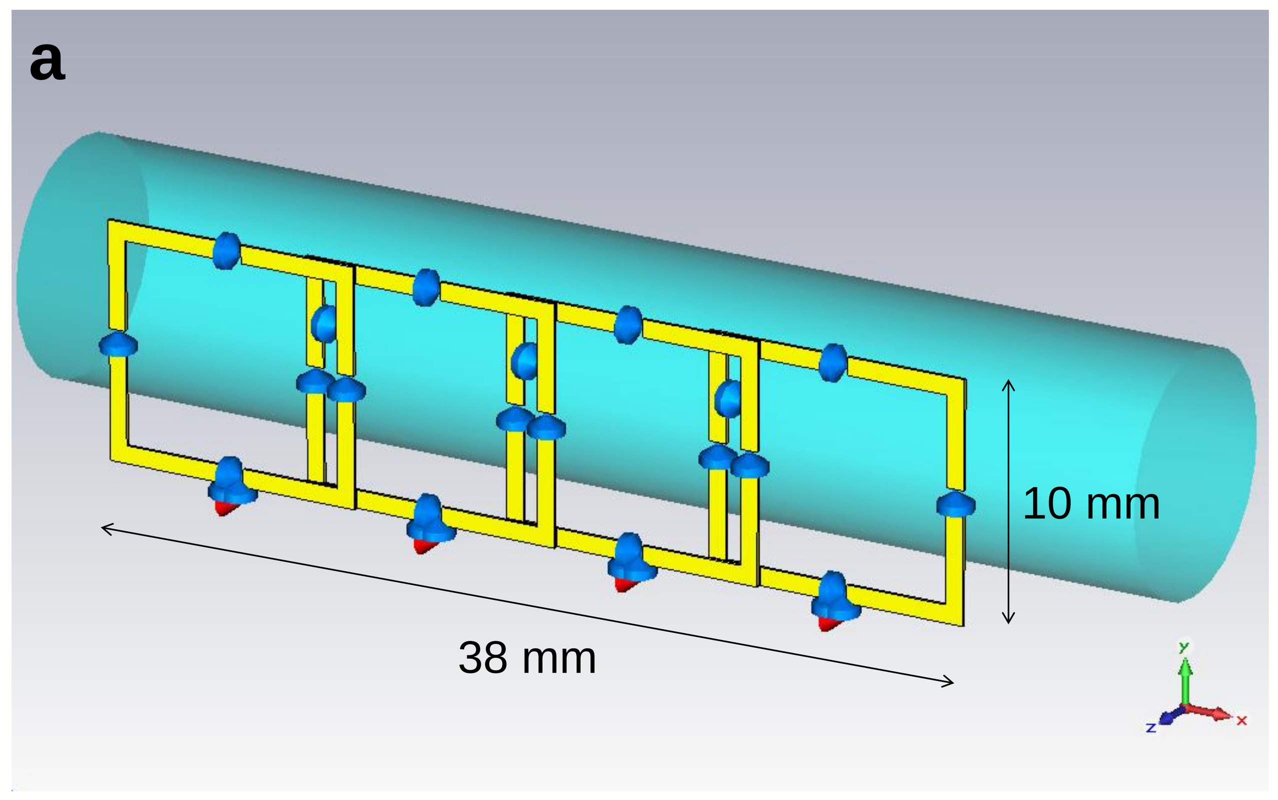
- Quadrature coil tests on phantoms show an improvement in absolute signal by a factor of 1.42 (theoretical = √2) when comparing the quadrature coil with a same sized linear coil.

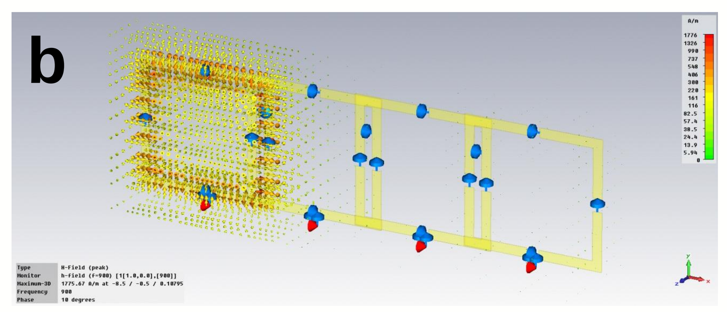
- Water phantom and *ex vivo* tissue MR data illustrate the feasibility of the quadrature surface coil for rodent head imaging in terms of signal homogeneity (fig. 3b) and penetration depth (figs. 3a, 4a, & 4b).

- *SNR* calculations (ROI at center of mouse head, 7mm from coil surface) indicate a two-fold improvement when comparing quadrature and single loop operating modes.

## 4-Element Linear Array Simulations on CST Microwave Studio:

- The 4-element linear array consists of four stacked 10x10 mm square loops meant for *in vivo* MR experiments on mouse spinal cords.



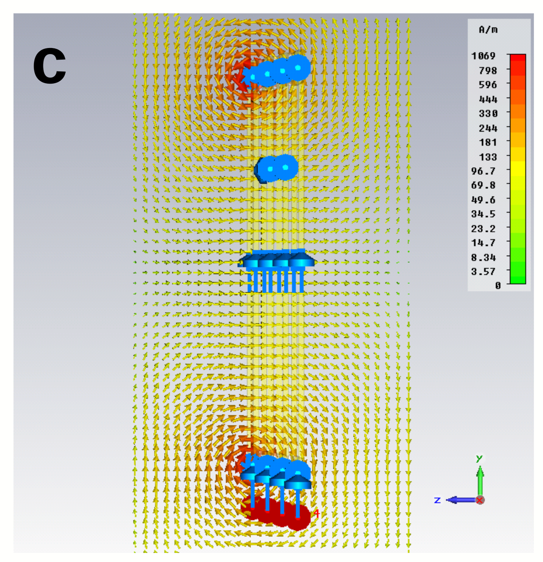




**Fig. 5:** (a) 4-element array model in CST; (b) magnetic field 3D vectors isolated to one of the four coils; (c) magnetic field 3D vectors from side view of array.

## Conclusions & Discussion:

•*Ex vivo* images indicate a homogeneous distribution in signal, which supersedes even potential *SNR* gains in importance for imaging applications at high fields.

•Extending these efforts to the 4-element array is very important for significant reductions of data acquisition times. Array coil construction is currently underway.